INTELLIGENCE **17**, 523–531 (1993)

Intelligence, Inspection Time, and Decision Time

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Relationships between Multidimensional Aptitude Battery (MAB) scores, inspection time (IT), choice reaction time (CRT), and the odd-man procedure (OMO) were investigated. IT was measured using a curve-fitting procedure that was less susceptible to variable task performance. IQ correlated significantly with IT ($r = -.624$) and OMO decision time (DT; $r = .365$) as well as with CRT DT ($r = -.28$). IT and OMO DT correlated .364. No significant relationships were found between these mental speed measures and Eysenck Personality Questionnaire–Revised (EPQ–R) dimensions of extraversion, neuroticism, and psychoticism, suggesting that motivational factors and strategies were minimized in this experiment.

INTRODUCTION

Terms such as quickness or speed are in common usage as synonyms for intelligence. In scientific psychology, too, intelligence has been modeled, among other things, as a consequence of mental speed. This is particularly true of theories that have studied the unitary aspect of intelligence, *g*, defined as the positive manifold existing among diverse tests of intelligence. In studying mental speed, we can assess at least two kinds of process: the speed of input, assessing time taken for stimuli to become represented as information in the brain, and speed of decision, the time during which the behavioral consequences of information unfold. Whereas these two hypothetically distinct periods may not reflect the true course of neural activity, nevertheless, they allow us to operationalize behaviors reflecting the speed at which individuals act.

For visual stimuli the process of sensory encoding can be defined as the processing of retinal signals into a short-term store, which can keep the stimulus available to consciousness indefinitely, provided rehearsal occurs. The speed at which this transformation occurs was first used explicitly as an index of intelligence by Nettelbeck and Lally (1976). They presented two vertical lines of

The experimental work reported in this article was undertaken at the Institute of Psychiatry, London. Thanks to Paul Barrett and Jackie for data collection services. We acknowledge the support of Philip Morris during this research.

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unequal length joined at the top by a horizontal crossbar. After a brief period this stimulus was replaced by a mask covering each stimulus line with a broad vertical bar. Subjects then reported on which side they thought the shorter line had been presented. This methodology allows control over the period for which stimulus information is available to the subject. More importantly, by assessing accuracy of recognition over a range of stimulus durations, it is possible to determine the time required for the subject to move from having light presented at the retina to achieving a stimulus-independent copy, this nervous state being protected from masking. Since the Nettelbeck and Lally study, a large body of research has investigated differences in inspection time (IT) as they relate to intelligence in different populations (Nettlebeck, 1987).

Turning to the second type of speed mentioned before, decision time (DT), several researchers, principally Arthur Jensen, have been involved in developing a model of intelligence based around the finding that the DT component of reaction time to simple choice stimuli, the time between stimulus onset and onset of the behavioral response, is related to intelligence. This research has been the subject of several recent reviews (Jensen, 1987). DT can be extracted from a reaction by providing subjects with a home key from which they move their finger to hit the target. The time elapsing between stimulus onset and the subject's finger leaving the home key provides the decision time, perhaps in addition to the inspection time (IT), although these two processes may overlap temporally. Some small constant is added that represents the time from which the efferent impulse is generated to the time at which the inertia of the finger is overcome and the home button becomes released. Jensen has concentrated on the Hick paradigm in which the increment of time required to process extra choices is recorded. By keeping all stimulus parameters constant and varying only uncertainty as to which stimulus will be presented, the Hick paradigm influences only the decision component of the reaction time. A distinct procedure, known as the odd-man (OMO), was developed by Frearson and Eysenck (1986) in response to their finding that some subjects' data do not conform to Hick's law and, also, to the theoretical point that the RT–IQ correlation may be supported by absolute response time to a complex choice itself, rather than the rate of change of this time as uncertainty increases.

The effect of personality type on IT and RT has not been well studied but there is some evidence that personality interacts with IT. Previous studies have indicated that subjects with extreme scores on the Manifest Anxiety or Eysenck Personality Questionnaire (EPQ) scales give longer ITs (Nettlebeck, 1973). Brebner and Cooper (1986) found that extroverts are more likely to use a strategy to aid them in the IT task and that, when such strategies are appropriate, extroverts obtained shorter ITs than did introverts. Because of these effects, we included measures of the personality dimensions of extroversion (E), neuroticism (N), and psychoticism (P) in our analyses as well as a test of impulsivity.

METHOD

Subjects

Subjects were 63 women (mean age = 37, *SD* = 10.1) and 25 men (mean age = 33.6, *SD* = 11.525) recruited as volunteers from the local government unemployment bureau and from within the Institute of Psychiatry. All subjects completed the EPQ–R (Eysenck, Eysenck, & Barrett, 1985) and the I–7 seven-factor test of impulsivity (Eysenck, Pearson, Easting, & Allsopp, 1958) as well as the OMO, choice reaction time (CRT), and IT tasks; 70 subjects also completed the Multidimensional Aptitude Battery (MAB; Jackson, 1984).

Apparatus

The CRT and OMO paradigms were both administered on an RT box functionally identical to that described by Jensen and Munro (1979). This box consists of a home button around which eight lights are arranged in a semicircle, each with a response key beneath it.

IT was measured using a custom stimulus presentation unit. Stimuli were formed by lighting various segments of an inverted U 150 mm high with a 40 mm wide top bar formed from rectangular LEDs (light-emitting diodes). A fixation light was centered between the arms 105 mm below the top bar. Each bar had four LED segments of equal length. A short line consisted of two lit segments, lighting three segments made the long line, and all four segments were lit on each side to form the mask.

The psychometric tests EPQ–R (Eysenck, Eysenck, & Barrett, 1985), MAB (Jackson, 1984), and I–7 (Eysenck, Pearson, Easting, & Allsopp, 1985) were administered in accordance with the directions outlined in their respective manuals.

Procedure

The IT task was administered using a standard staircase procedure (Wetherill & Levitt, 1965) with the variation that the procedure terminated in a phase that required nine consecutive correct trials to decrease stimulus duration, rather than after a set number of reversals. In addition to the typical estimate of psychometric performance, this modification directly measures the stimulus duration at which subjects are 90% accurate.

On each trial a warning pip was presented through headphones, synchronous with a small red diode appearing lit on the stimulus box. After a brief delay, a left- or right-side short stimulus was presented. The mask was then energized after an interval varying from 500 ms downwards. This sequence is presented in Figure 1.

Both the OMO and CRT were administered in a manner similar to that used by Frearson and Eysenck (1986). The subject sat before the box and used his or her preferred hand to respond. Each trial consisted of a warning tone (1000 Hz and

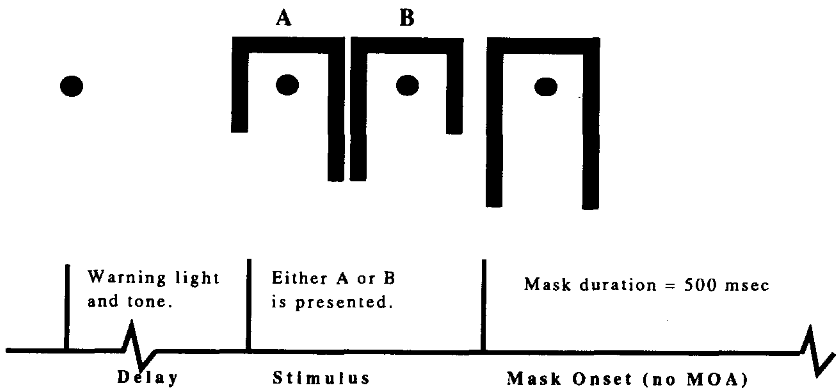

Figure 1. Presentation sequence for each trial; valid responding could occur at any time following stimulus onset.

70 dB SPL for 54 ms) followed, after a random interval of 1–4 s, by a choice stimulus. Following a practice session lasting until subjects announced that they felt confident with the procedure (typically 1.5 min and never more than 11 trials), subjects completed either 20 or 30 error-free trials on the OMO and CRT procedures. The first 29 subjects completed 20 trials, and the remaining 59 subjects completed 30. The additional trials, given to some subjects to explore reliability parameters, did not significantly affect either the mean or the variance of RT scores.

For CRT the subject responded to a single light on each trial but it was uncertain as to which of the eight possible lights would be presented. In the case of the OMO, three of the eight stimulus lights were lit in a pattern arranged so that two lights were closer to each other than the third OMO stimulus. The task was to determine as quickly as possible which light was the OMO and to depress the appropriate response key.

In all cases the time for the subject to lift his or her finger from the home button (DT) and the subsequent time to hit a target key (movement time or MT) were recorded separately under computer control. Response accuracy was also logged.

RESULTS

IQ and IT

To assess IT, the raw data were converted to proportion-correct scores achieved at each presented level of stimulus duration, with the proviso that if discrimination fell below 50% then it was set equal to .50 (the chance guessing rate). A psychometric function was then fitted to the resulting array of accuracy scores.

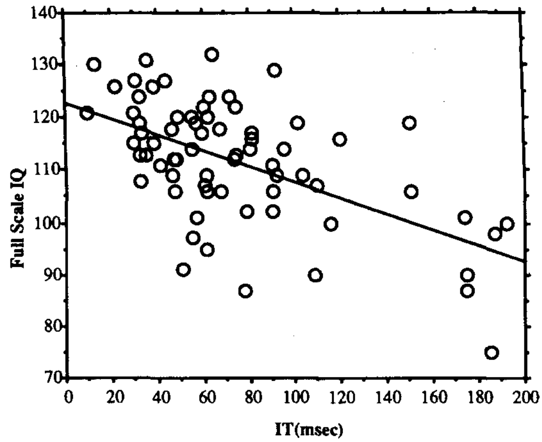

Figure 2. Graph of IT scores against IQ scores (IT values derived from the filtered IT data).

As responding was not biased, IT at $d' = 1$ was estimated by solving for duration when the proportion of correct responses was .76. These data are presented in Figure 2.

For 6 of the 70 subjects, this procedure was not applicable. These subjects gave chance performance at stimulus durations longer than those at which they showed a high level of accuracy. Because of this, the polynomial bounced between 50% and 100%, and gave a meaningless estimate, as well as a very high mean square error. The IQs of these 6 subjects with irregular IT performance did not differ from those of the remainder of the sample (unpaired $t = .818$, n.s.). Examples of regular and irregular records and their best-fit polynomials are shown in Figure 3 and Figure 4, respectively. Three strategies were adopted to cope with these subjects: (1) accepting the irregular data as valid and including

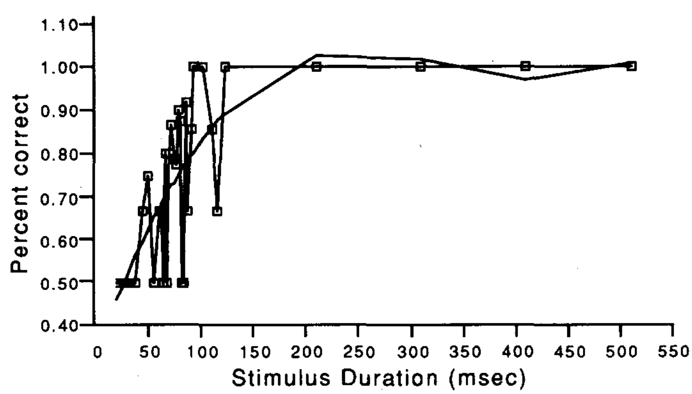

Figure 3. A typical subject's IT data and best-fit curve.

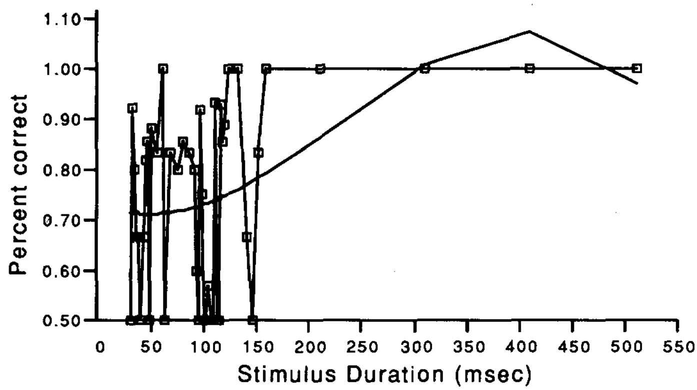

Figure 4. IT record from 1 of the 6 atypical subjects.

these subjects in the analysis; (2) excluding these subjects; and (3) filtering their data to remove sudden discontinuities in discrimination.

For the total sample, the correlation between raw IT scores and MAB full scale IQ was highly significant ($r = -.447$, $p = .0001$). Removing the 6 subjects for whom a psychometric function could not be fitted raised the correlation with IQ to $-.624$ ($p < .0001$). Retaining all the subjects but discounting runs of errors at relatively easy durations ("filtering") gave a correlation of $-.564$.

As can be seen in Table 1, IT was correlated more highly with total IQ than with either the Verbal or Performance subtests. Performance IQ was nonsignificantly superior to verbal IQ as a predictor of IT.

IT and Personality

Correlations between IT and E, N, P, and L were low ($-.146$, $-.143$, $-.14$, and $-.259$, respectively). It was thought possible that the unreliable performance of some subjects may have been caused by personality variables. However, this appears unlikely as the 6 subjects for whom it was hard to fit a psychometric function could not be distinguished by *t* test on any of E, N, P, L, or venturesomeness scales.

TABLE 1
Correlations Between IT and Full Scale, Verbal, and Performance IQ

	IT(ms)	Full Scale	Verbal	Performance
IT(ms)	1			
Full scale IQ	−.624	1		
Verbal IQ	−.568	.929	1	
Performance IQ	−.588	.940	.749	1

Note. IT = inspection time; IQ = Full scale Multidimensional Aptitude Battery score.

RT and IQ

OMO median DT correlated −.365 ($p < .005$) with full scale IQ and +.364 ($p < .055$) with IT. These values are in line with other values reported in the literature (Jensen, 1987) and, here, compare favorably with the correlation between the two RT measures, OMO and CRT, which was .425. Correcting for restriction or range increased the correlation between OMO median DT and IQ to −.53. The formula used for correction was:

$$R_{12} = \frac{r(s_1/s_2)}{\sqrt{1 - r^2 + [r^2\,(s_1^2/s_2^2)]}}$$

where R_{12} = the range-corrected correlation, r is the uncorrected correlation and s_1 and s_2 are the population and sample standard deviations respectively. The MAB sample mean was 111.7 (SD = 11.67).

A number of alternative measures can be derived from RT. In addition to DT, these include MT, difference scores of these two variables, as well as error scores and the standard deviation of DT. As can be seen in Table 2, these measures showed only a weak relationship with IQ. Other researchers, including Longstreth (1984), have argued that the DT–IQ relationship may be due to a learning effect, such that brighter subjects simply learn the task more speedily. If true, this reduces the Jensen paradigm from a demonstration of neural speed underlying *g* to simply another puzzle that brighter people solve quickly.

In the data here, no significant relationship was found between early and late trials and the DT–IQ relationship. Taking the first half of OMO trials compared

TABLE 2
Correlations Between the IT, IQ, and RT Variables

Variable	IT	IQ
CRT Median DT	.063	−.28
CRT Median MT	.077	−.097
CRT DT–MT	.003	−.131
CRT DT *SD*	.229	−.275
CRT MT *SD*	−.038	−.039
CRT DT-MT *SD*	.024	−.080
CRT errors	−.174	.228
OMO median DT	**.364**	**−.365**
OMO median MT	.100	−.185
OMO DT–MT	**.370**	**−.316**
OMO DT *SD*	.264	−.227
OMO errors	−.021	.053

Note. IT = inspection time; IQ = Full scale Multidimensional Aptitude Battery score; CRT = choice reaction time; OMO = odd man; DT = decision time; MT = movement time; *SD* = standard deviation. Correlations greater than .3 appear in boldface type.

to the total OMO mean gave correlations with IQ of .357 and .370, respectively. This is in accord with previously reported data (Jensen & Vernon, 1986).

DISCUSSION

The IT–IQ correlation was improved both by filtering the data to remove errors at easy durations and, alternatively, simply excluding subjects whose data showed such errors. Because including highly variable trial data dilutes the IT–IQ relationship, future research may be improved by the adoption of some form of ogive fitting and data filtering in order to best estimate subject's level of performance independent of lapses of attention. Regarding the within-subject variations in performance themselves, in all probability, those trials on which subjects performed at chance were influenced by momentary lapses of attention, understandable in a procedure that demands a high level of vigilance for as much as 15 min. It appears that in the highly motivating laboratory situation the best explanation for these is that they are lapses of attention distributed randomly with respect to personality and intelligence. In general, the absence of personality effects in this study may indicate that there were few opportunities for strategy use in this paradigm, thus minimizing the effect of any tendency to solve the tasks using methods other than simple speed of apprehension and decision.

It is also interesting to note that the speed-of-processing measures correlated similarly with both Performance and Verbal measures of IQ, with correlations being highest to the more reliable sum of these two scores. This indicates that these tasks, although based on behavioral performance, are reflections of a central process such as *g*, rather than specific task abilities.

The alternative measures derived from the RT tasks did not relate to IQ as well as did the mean DT measures. Practice effects could not explain the IQ–RT relationship in these naive subjects, further strengthening the hypothesis that mental speed is a principal determinant of intelligence rather than attitudes or dispositions to perform well. Variance in DTs did not correlate with IQ as well as the mean DT itself (see Table 2). This supports models that view mean DT as a direct measure of speed rather than as a consequence of errors in responding as reflected in distribution variance.

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